Responses to an Estrogenic Growth Promoter in Beef Steers Fed Varying Nutritional Regimens[1]

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ABSTRACT: We investigated the influence of DM and(or) energy intake and dietary CP levels on the performance and nitrogen (N) retention of beef steers with and without growth promoter implants. In Exp. 1, four implanted (Synovex-S, 200 mg of progesterone plus 20 mg of estradiol benzoate) Angus steers and four Angus steers that were not implanted were assigned to concurrent 4 × 4 Latin squares. Initial BW averaged 296 kg. Each square consisted of moderate and moderately high DM intake treatments (4 and 6 kg/d) and low and adequate CP intake treatments (450 and 600 g/d) in a 2 × 2 factorial arrangement. Periods were 2 wk of adaptation, 5 wk of growth, and 1 wk of balance collection. Experiment 2 consisted of two replicates of 32 Hereford steers each (initial BW 324 kg). Each replicate was a 4 × 2 factorial in which steers were individually fed for 63 d. All steers had ad libitum access to a 60% corn-based concentrate diet containing either 7.9, 10.0, 12.1, or 14.6% CP (DM basis), and steers were either implanted or not implanted with Synovex-S. Experiment 3 was similar to Exp. 2 except that all steers (initial BW 315 kg) received a low-protein diet (7.6% CP) with calculated energy densities of either 1.86, 2.04, 2.22, or 2.42 Mcal ME/kg DM, and steers were limited to an equalized DM intake of 9.5 kg daily. In Exp. 1, gains for the low CP, moderate and moderately high DM intakes and the adequate CP, moderate and moderately high DM intakes were 240, 555, 208, and 730 g/d, respectively, for steers not implanted and 333, 643, 488, and 988 g/d, respectively, for implanted steers (SEM = 102 g/d). Respective values for retained N were .13, .18, .16, and .26 g/kg $BW^{.75}$ and .13, .15, .22, and .29 g/kg $BW^{.75}$ (SEM = .04 g/kg $BW^{.75}$). Implant response was greater (CP × implant, $P < .01$) for both gain and retained N when adequate CP compared to low CP diets were fed. For Exp. 2, the lowest CP diet reduced ADG (.97 vs 1.27 kg/d) and efficiency of gain (100 vs 120 g gain/kg DM). Synovex-S was less effective in improving efficiency for the lowest protein diet than for the other diets (11.7 vs 20.2%). During Exp. 3, neither Synovex-S nor dietary energy influenced gain and efficiency. We concluded that adequate dietary protein is necessary to optimize the response to estrogenic growth promoters and that the low response under inadequate protein and energy intake is not improved by increasing the energy density of the diet.

Key Words: Energy Intake, Growth, Growth Promoters, Nitrogen Balance, Protein Intake, Steers

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Introduction

Implants with estrogenic activity have been used extensively as growth promoters for the past 40 yr to improve the performance of growing and finishing beef steers. In general, these materials increase the amount of gain per unit of feed intake from 10 to 15% and in most situations increase feed intake (Rumsey, 1985). The improved performance is usually greater during the early portion of the growing and finishing period than during the later portion.

Synovex-S (200 mg of progesterone plus 20 mg of estradiol benzoate) caused a 25% increase in protein gain of growing beef steers (Rumsey et al., 1981; Rumsey, 1982). This change in tissue gain was accompanied by little change in diet digestibility, but a reduction in urinary nitrogen excretion (Rumsey and Hammond, 1990) and an increase in metabolic rate (Rumsey et al., 1980) and circulating IGF-I concentrations (Breier et al., 1988; Rumsey and Elsasser, 1989) have been observed. As intake of a given diet was reduced from near ad libitum to a submaintenance level, response to diethylstilbestrol and Synovex-S became negative (Oltjen et al., 1973; Rumsey and Hammond, 1990). Re-

[1]Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by USDA and does not imply its approval to the exclusion of other products that may be suitable.

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Table 1. Ingredient and chemical composition of experimental diets used in Exp. 1

Item	Moderately high DM intake		Moderate[a] DM intake	
	Adequate CP	Low CP	Adequate CP	Low CP
Ingredient, % dry basis				
Cracked corn	42.0	46.5	30.5	37.5
Wheat straw[b]	20.0	20.0	20.0	20.0
Cottonseed hulls	20.0	20.0	20.0	20.0
Soybean meal (44% CP)	7.0	2.5	18.5	11.5
Molasses	9.0	9.0	9.0	9.0
Trace mineral salt[c]	1.0	1.0	1.0	1.0
Calcium phosphate	1.0	1.0	1.0	1.0
Vitamins A and D[d]	+	+	+	+
Composition, dry basis				
Analytical CP, %	9.9	7.4	14.5	12.4
Estimated ME, Mcal/kg	2.4	2.4	2.4	2.4
Protein:energy	4.13	3.08	6.04	5.16

[a]Percentage CP in the moderate DM intake diets was higher than in the moderately high DM intake diets to equalize CP intake across DM intake levels.

[b]Straw was ground through a 10-mm screen, and the mixed diet was pelleted through a 1.6-cm die.

[c]Contained not less than 96.0% salt, .25% Zn, .20% Mn, .125% Fe, .025% Cu, .005% I, and .005% Co.

[d]Diets were supplemented with 2,000 IU vitamin A and 250 IU vitamin D per kilogram of diet.

sponse to Synovex-S would be expected to be sensitive to both dietary CP and energy intakes, thus a protein × energy interaction on response to Synovex-S is possible.

The objective of this study was to determine the effects of the estrogenic growth promoter Synovex-S on 1) growth and N balance of beef steers fed low or adequate dietary CP intakes at moderate or moderately high DM intakes, 2) performance of feedlot steers fed varying levels of dietary protein, and 3) performance of steers fed varying dietary energy levels with inadequate dietary protein.

Materials and Methods

Animal Care. The study was conducted according to the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Consortium, 1988). The report by Rumsey and Hammond (1990) along with typical intakes observed in our Beltsville feeding facilities were used as guides in setting intakes for this study.

Experiment 1. Eight medium-framed Angus steers (initial BW 296 kg) were used. During a 3-wk preliminary period, the steers were trained to lead with a halter and accustomed to collection crates. Throughout the experiment, when the steers were not in collection crates they were housed in individual indoor pens (1.9 × 3.6 m) with outdoor runs (1.9 × 5.7 m) and had continual access to water. During the preliminary period, the steers were all fed the same diet (Table 1; moderately high intake, adequate dietary CP). The moderately high intake level was based on intakes from a previous balance trial that compared implant response to varying intake (Rumsey and Hammond, 1990) and to ensure complete consumption by the steers of their daily allotments of experimental diets while in digestion crates. Adequate dietary CP was based on the performance responses that had been obtained for Exp. 2 of this study.

The experiment was conducted from the spring to fall seasons starting in mid-April following Exp. 2. Housing in individual pens was at ambient temperatures with natural ventilation. The collection crates were in a heated and air-conditioned room maintained between a minimum of 15°C and a maximum of 21°C.

At the beginning of the experiment, the steers were paired on the basis of BW. A pair was assigned at random to one of four dietary treatments (two steers per treatment, diets shown in Table 1). Within each pair, the steers were randomly assigned to either no implant or ear implant treatments (Synovex-S, Fort Dodge Laboratories, Division of American Home Products, Fort Dodge, IA). The experimental design was a replicated 4 × 4 Latin square with the replications conducted simultaneously; one replication containing the control steers and the other containing the implanted steers. The dietary treatment sequence within squares was balanced across periods for dietary treatment, and treatment sequence within each replication was the same. Each of the four periods was 8 wk, consisting of 2 wk of intake transition, 5 wk of feeding, and 1 wk in collection crates (2 d of adaptation and 5 d of total collection for digestion and N balance determinations).

The diets were formulated to provide the same quantitative low or adequate amounts of dietary CP intakes (NRC, 1984) when fed at two levels of DM intake (moderate and moderately high). The moderate level of intake was calculated to be two-thirds that of moderately high intake level, and the low protein intake was calculated to be three-fourths that of the adequate level.

At the start of the experiment, steers assigned to the implant treatment were implanted in the right ear per manufacturer's recommendations. Care was taken not to crush the implants and a single suture was used to close the skin opening caused by the implant needle to prevent implant loss via the s.c. channel created by implanting. At the start of each subsequent 8-wk period, previous implants were removed, and the same steers were reimplanted. Implanting was alternated between right and left ears.

The steers were weighed on two consecutive days at the end of each transition, once weekly during the 5-wk feeding, on two consecutive days before being placed in metabolism crates, and once when removed from the crates. During the study, steers were offered half their daily allotment of feed at 0800 and the other half at 1600, except for 1 wk before and during the collection period, when steers were fed at 0900 and 2100. Feed intake was recorded daily throughout the experiment. Weekly samples of diet during the 5-wk feeding and

Table 2. Ingredient and chemical composition of experimental diets used in Exp. 2 and 3

	Estimated CP level, % (Exp. 2)				Estimated ME level, Mcal/kg (Exp. 3)			
Item	8	10	12	14	2.42	2.22	2.04	1.86
Ingredient, % dry basis								
Cracked corn	49.0	43.5	38.0	32.5	49.0	37.2	25.4	13.6
Wheat straw[a]	20.0	20.0	20.0	20.0	20.0	25.0	30.0	35.0
Cottonseed hulls	20.0	20.0	20.0	20.0	20.0	25.0	30.0	35.0
Soybean meal	—	5.5	11.0	16.5	—	1.8	3.6	5.4
Molasses	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Trace mineral salt[b]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Calcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vitamins A and D[c]	+	+	+	+	+	+	+	+
Analysis								
DM, %	90.5	91.0	91.0	91.0	91.1	92.1	92.8	93.3
CP, % of DM	7.9	10.0	12.1	14.6	7.4	7.6	7.6	7.9

[a]Straw was ground through a 10-mm screen, and the mixed diet was pelleted through a 1.6-cm die.
[b]Contained not less than 96.0% salt, .25% Zn, .20% Mn, .125% Fe, .025% Cu, .005% I, and .005% Co.
[c]Diets were supplemented with 2,000 IU vitamin A and 250 IU vitamin D per kilogram of diet.

daily samples during the total collection were composited by steer and within the respective periods for analysis. During the total collections, daily amounts of feces and urine for each steer were recorded, and 10% aliquots by weight were frozen. Urine was collected daily in containers with HCl solution to maintain collected urine pH at approximately 2.0. Just before analysis after all collections for the experiment were complete, the daily aliquots were composited (thorough mixing of thawed daily aliquots) by steer and by collection period.

Feed, orts, and feces samples were analyzed for DM (65°C to a constant weight). Feed, orts, non-dried feces, and urine were analyzed for total N with macro-Kjeldahl procedures. For the non-dried feces and urine, representative samples for analysis were obtained in duplicate after mixing and compositing the daily aliquots.

Experiment 2. This experiment was designed to compare the performance of young beef steers fed different levels of protein and either implanted with Synovex-S or not implanted. The experiment consisted of two identically designed trials conducted in the same feeding facilities during an 8-mo period. Trial 1 was from July to September, and Trial 2 was from December to February. Each trial consisted of 32 Hereford steers assigned to a factorial arrangement of treatments so that average BW was equalized across treatment groups. Eight steers were assigned to each of four diets formulated to contain estimated CP levels (DM basis) of either 8, 10, 12, or 14% and an estimated metabolizable energy value of 2.42 Mcal/kg DM. Four steers in each diet group were implanted with Synovex-S. The initial BW of the steers averaged 310 ± 29 kg for Trial 1 and 337 ± 20 kg for Trial 2.

Formulations and laboratory DM and CP analyses of the experimental diets are shown in Table 2. All diets contained 40% roughage on an as-fed basis consisting of half wheat straw and half cottonseed hulls. The concentrate portion of the diets was based on corn, and protein was increased by replacing part of the corn with soybean meal.

The steers were housed in individual outside pens on a concrete pad with a partial roof for shade and shelter. Water was available continuously. Before each trial, all steers were adapted to a 14% CP diet fed for ad libitum consumption over a 2-wk period. At the end of the 2nd wk, the steers were weighed on two consecutive days, implanted, and switched to their respective experimental diets. All steers had ad libitum access to feed. Steers were fed half their daily feed at approximately 0800 and 1600. Individual daily feed intakes were recorded for 63 d, and BW were obtained weekly. During the final week, steers were again weighed on two consecutive days. Average daily gain of each steer was determined from the regression of BW over days. Feed was sampled weekly and feed refusals were sampled daily and composited weekly for DM and Kjeldahl N analyses.

Experiment 3. This experiment was designed to compare the performance of young, growing beef steers fed a low-protein diet containing four levels of energy and either implanted with Synovex-S or not implanted. We determined whether the limited growth response to Synovex-S obtained under conditions of limited dietary protein could be increased by increasing dietary energy intake. The design, location, management, and measurements were the same as for Exp. 2, except that daily intakes were equalized across all treatments at a level just below ad libitum to eliminate intake differences between steers that were implanted and not implanted. This experiment was conducted the year following Exp. 2 during the same months of the year; Trial 1 was from July to September, and Trial 2 was from December to February. The formulations and analyses of the experimental diets are shown in Table 2. The four estimated levels of metabolizable energy were 2.42, 2.22, 2.04, and 1.86 Mcal/kg DM. The formulation for the highest energy diet was the same as the 8% CP diet in Exp. 2, and energy was varied by incrementally varying both wheat straw and cottonseed hulls in relation to corn. Soybean meal was added to maintain a comparable protein level across all diets.

Statistical Analysis. For data from Exp. 1, BW gain (regression coefficient of weekly BW over 5 wk of feeding) and metabolism measurements were analyzed with analyses of variance for a replicated Latin square (Snedecor, 1957) using the ANOVA procedure of SAS (1988). Replicate was Synovex-S implant vs no implant. The model included CP level, DM intake level, and CP $\times$ DM intake factors within square. Also included were square, square $\times$ DM intake, and square $\times$ CP interactions tested against residual mean square. For Exp. 2, ADG, intake data, and calculated efficiency values were evaluated as a replicated factorial with analyses of variance using the ANOVA procedure of SAS (1988). Main effects were trial (replicate), CP level, and implant. Effects of replicate or trial in this experiment were confounded with season. For efficiency of gain, means for CP levels were compared using the following orthogonal contrasts: 8% vs 10, 12, and 14% CP; 10 and 12% vs 14% CP; and 10% vs 12% CP. Also, regression procedures were used to compare efficiency values across protein levels between implanted steers and steers not implanted. Statistical analysis of the data from Exp. 3 was the same as for Exp. 2.

Results and Discussion

Experiment 1. Table 3 presents the individual treatment means for the performance and metabolism measurements for Exp. 1. Dry matter intakes, as designed, were different ($P < .01$) between the moderate and moderately high DM intake treatments and were the same across both CP intake and implant treatments. Body weight gain was greater ($P < .01$) for the moderately high DM intake treatment (729 g/d) than for the moderate DM intake treatment (317 g/d), greater ($P < .05$) for the adequate CP treatment (604 g/d) than for the low CP treatment (443 g/d), and greater ($P < .05$) for implanted steers (613 g/d) than for steers not implanted (433 g/d).

Body weight gain was also affected by the DM intake $\times$ CP intake interaction ($P < .01$). The effect of increasing CP intake on gain was less when steers were fed at moderate DM intake (62 g/d, difference between adequate and low CP intake treatments at moderate DM intake) than when moderately high DM intake was fed (260 g/d). This was expected, because energy was not adequate at moderate DM intake for optimum growth. Similarly, Griffiths (1978) reported that level of protein intake influenced gain only at a high level of energy intake, primarily as a result of favorable effects on digestibility.

The gain response to implant treatment was similar across DM intake levels, suggesting that energy was not limiting the response to implants across DM intake in this experiment. This differs from the results of Preston and Burroughs (1958) with diethylstilbestrol in lambs, which suggested energy intake influenced growth response to estrogenic growth promoters. However, Prior et al. (1978) did not observe a response difference across energy intake levels when steers were implanted with Synovex-S. Additional energy above a certain level of intake may not be required for optimal response to estrogenic growth promoters.

The effect of implant treatment on BW gain was greater ($P < .01$) when adequate CP was fed (269 g/d, difference between implant and no implant treatments at adequate CP intake) than when low CP was fed (91 g/d). This interaction is consistent with the results of Preston and Burroughs (1958). The gain data indicate that under conditions of varied moderate energy intakes, adequate CP intake is needed to optimize the response to Synovex-S implants.

The growth response to Synovex-S may be partly mediated through the somatotropic IGF-I axis. Plasma concentrations of IGF-I were greater in Synovex-S-treated steers (Rumsey and Elsasser, 1989). Breier et al. (1988) have demonstrated that estradiol increases the number of hepatic high-affinity somatotropic receptors in adequately fed steers, whereas steers fed a limited level of nutrition did not contain hepatic high-affinity somatotropic receptors. These findings indicate an increased sensitivity to somatotropin at the tissue level. Although it is not possible to separate the effects of energy and protein in their study, their results could help explain the relative differences in BW gain between the implant treatments at low and adequate CP intakes seen in the current experiment if response to estrogenic growth promoter is mediated through affects on GH mechanisms.

On average, digestibility of DM was lower ($P < .01$) for moderately high DM intake (63.8%) than for moderate DM intake (72.0%) and greater ($P < .01$) for the adequate CP treatment (70.0%) than for the low CP treatment (65.8%). The interaction ($P < .01$) between DM intake and CP intake was due primarily to a depressed digestibility for the moderately high DM intake-low CP treatment (Table 3). The interactions ($P < .01$) of DM intake $\times$ implant and CP intake $\times$ implant were primarily a reflection of the low digestibility for the moderately high DM intake, low CP treatment; DM digestibility was particularly depressed for this treatment in the implanted steers. This could be caused by a depressed ruminal digestion associated with low dietary protein (Williams et al., 1953).

Crude protein digestibility was lower ($P < .01$) for moderately high DM intake (48.3%) than for moderate DM intake (65.7%) and greater ($P < .01$) for the adequate CP treatment (61.7%) than for the low CP treatment (52.2%). Crude protein digestibility was affected by a CP intake $\times$ DM intake interaction ($P < .01$). The difference in CP digestibility due to increasing CP intake was greater when moderately high DM intake was fed (13.6 percentage units) compared to when moderate DM intake was fed (5.4 percentage units). This interac-

Table 3. Effect of DM and CP intakes on growth, diet digestibility, and retained nitrogen (N) of beef steers either not implanted or implanted with the estrogenic growth promoter Synovex-S (Exp. 1)

	Not implanted				Implanted				
Item	ip[a]	iP	Ip	IP	ip	iP	Ip	IP	SEM[b]
Performance									
DM intake, kg/d[c]	4.1	4.1	6.0	6.0	4.1	4.1	5.9	6.0	NS
ADG, g/d[cdefg]	240	208	555	730	333	488	643	988	102
Digestibility of									
DM, %[cfij]	72.8	68.6	63.0	70.4	73.9	72.5	53.3	68.6	1.8
CP, %[cfgj]	63.1	66.6	41.9	57.0	62.9	70.1	41.1	53.2	2.3
N balance									
Intake, g/d[jk]	77.3	98.3	73.1	93.6	77.3	89.0	76.0	96.9	<1.0
Feces, g/d[cf]	28.3	32.8	42.6	39.9	28.5	26.4	44.7	45.4	.5
Urine, g/d[cj]	37.6	52.7	15.4	31.7	37.1	46.0	17.6	26.4	.7
Retained, g/d[egh]	11.4	12.9	15.1	22.0	11.7	18.8	13.6	25.1	3.3

[a]ip = moderate DM intake and low CP, iP = moderate DM intake and adequate CP, Ip = moderately high DM intake and low CP, and IP = moderately high DM intake and adequate CP.
[b]SEM = common standard error of the mean calculated from analysis of variance. NS = not statistically significant.
[c]DM intake effect ($P < .01$).
[d]Implant main effect ($P < .05$).
[e]CP intake main effect ($P < .05$).
[f]CP intake × implant interaction ($P < .01$).
[g]DM intake × CP intake interaction ($P < .01$).
[h]DM intake effect ($P < .05$).
[i]DM intake × implant interaction ($P < .01$).
[j]CP intake main effect ($P < .01$).
[k]CP intake × implant interaction ($P < .05$).

tion reflects the noticeably lower CP digestibility for the moderately high DM intake-low CP treatment. Unlike DM digestibility, this reduced CP digestibility was similar in the implanted steers and steers not implanted.

By design, N intake during total digestibility and retained N collections was greater ($P < .01$) when adequate CP was fed (94.5 g/d) than when low CP was fed (75.9 g/d). Fecal N was greater ($P < .01$) when moderately high DM intake was fed (43.2 g/d) than when moderate DM intake was fed (29.0 g/d). Urinary N was lower ($P < .01$) when moderately high DM intake was fed (22.8 g/d) than when moderate DM intake was fed (43.4 g/d), probably reflecting the limited energy intake of the moderate intake treatment compared with the moderately high intake treatment. Urinary N was greater ($P < .01$) when adequate CP was fed (39.2 g/d) than when low CP was fed (26.9 g/d). Although urinary N excretion was not significantly affected by implant in this experiment ($P > .10$), the amount excreted was approximately 8% lower for the implanted steers than for the steers not implanted (34.4 vs 31.8 g/d), consistent with the use of estrogenic growth promoters (Rumsey, 1985).

Retained N was greater ($P < .05$) when moderately high DM intake was fed (19.0 g/d) than when moderate DM intake was fed (13.7 g/d) and was greater ($P < .05$) when adequate CP was fed (19.7 g/d) than when low CP was fed (13.0 g/d). Retained N was affected by a DM intake × CP intake interaction ($P < .01$). The response to CP intake was greater when moderately high DM intake was fed (9.2 g/d) than when moderate DM intake was fed (4.3 g/d). As with urinary N, retained N was not significantly affected ($P > .10$) by implant, although across treatments retained N was numerically 12% greater for implanted steers than for steers not implanted (17.3 vs 15.4 g/d). If retained N was calculated per unit of metabolic body weight, then, in addition to the main effects of DM intake and CP intake being significant ($P < .05$), the response to implant was greater ($P < .01$) when adequate CP was fed (4.5 g/(d·BW$^{.75}$) than when low CP was fed (–1.5 g/[d·BW$^{.75}$). This interaction was similar to the results for BW gain in these steers.

Experiments 2 and 3. For Exp. 2, daily DM intake and ADG are summarized in Table 4. Diet DM intake was different ($P < .01$) among dietary CP levels. The highest intakes were obtained for the 10 and 12% CP diets and the lowest were for the 8 and 14% CP diets. This intake pattern across CP levels was consistent across trials but is not totally understood, except that a somewhat lower DM intake may be expected for the lowest CP level compared to the other levels. Implant treatment did not significantly influence DM intake, but numerically the implant steers averaged 6% greater DM intake than the steers not implanted. Average daily gain was different ($P < .01$) among dietary CP levels and was 25.5% greater ($P < .01$) for the implanted steers than for the steers not implanted. The best gains were generally achieved with the 10 and 12% CP diets. The poorest average performance was with the 8% CP diet. Average daily gain was not affected by the dietary CP level × implant interaction ($P > .10$).

Efficiency of gain was calculated as grams of live BW gain per kilogram of feed DM intake. Dietary CP level influenced ($P < .01$) gain/DM intake. Orthogonal contrasts indicated that gain/DM intake for the 8% CP diet was lower ($P < .01$) than for the 10 to 14% CP diets, and efficiency was not different among the 10 , 12, and 14% CP diets. The dietary CP level × implant interaction was significant ($P < .05$), indicating a greater response to implants under conditions of adequate dietary CP. The data were fit with regression analysis within implant treatment. Efficiency of gain increased within each implant treatment in a quadratic manner ($P < .05$) as dietary CP level increased. The response to implants for gain/DM intake was 9.6, 17.3, 23.9, and 19.4% for the 8, 10, 12, and 14% dietary CP treatments, respectively.

Daily DM intake, ADG, and efficiency of gain for Exp. 3 are summarized in Table 4. Throughout Exp. 3, there was a small but consistent difference in intake between energy levels due to some feed refusal by steers fed the highest energy level. Intake was not different ($P > .10$) between implanted steers and steers not implanted. Neither ADG nor efficiency of gain was influenced ($P > .10$) by implant or energy level treatments in this experiment.

Several formulations containing estrogenic activity used for stimulating weight gain in growing and finishing cattle have been developed since the mid-1950s. Studies at the Beltsville Agricultural Research Center with estrogenic growth promoters have included diethylstilbestrol, a synthetic compound, and Synovex-S. Both diethylstilbestrol and Synovex-S slightly increase basal metabolic rate, as indicated by increased fasting heat production, fasting nitrogen excretion, and heart rate (Rumsey et al., 1973; 1980; Rumsey and Hammond, 1990), and during the normal feedlot period of from 300 to 500 kg BW, they increase protein deposition by approximately 25% (Rumsey et al., 1981; Rumsey, 1982). Data from our laboratory suggest that increased synthesis rate, not a change in degradation rate, as discussed by Buttery et al. (1978), is the primary factor influenced by estrogenic growth promoters (Rumsey et al., 1979, 1998; Claypoole et. al., 1987). Thus, increased metabolic and protein synthesis rates are factors that suggest both dietary energy level as well as protein level may be important for optimizing the growth response to estrogenic growth promoters in growing beef cattle. These factors are of practical interest relative to expected production responses.

Experiments reported in the literature suggest that dietary protein and energy levels are important for the response achieved from hormonal growth promoters. Tillman and Brethour (1957) reported that lambs fed

Table 4. Effect of Synovex-S implants on performance of steers fed varying dietary CP level (Exp. 2) and ME level (Exp. 3)

	Dietary CP level, %								
	8		10		12		14		
Item	–[a]	+[a]	–	+	–	+	–	+	SEM
Exp. 2									
No. of steers	8	8	8	8	8	8	8	8	—
Initial BW, kg	323	322	321	324	324	323	324	327	8.8
Performance									
DM intake, kg/d[b]	9.10	9.82	11.15	11.14	10.65	11.28	9.28	10.27	.56
CP intake, g/d[c]	718	775	1,115	1,114	1,288	1,364	1,354	1,499	—
ADG, kg[bd]	.87	1.06	1.22	1.43	1.17	1.52	.99	1.31	.10
Gain/DM intake, g/kg[bef]	94.8	105.9	109.7	128.7	109.4	135.5	107.4	128.2	8.2
	Dietary ME level, Mcal/kg								
	1.86		2.04		2.22		2.42		
	–	+	–	+	–	+	–	+	
Exp. 3									
No. of steers	8	8	8	8	8	8	8	8	—
Initial BW, kg	320	313	317	316	315	315	322	311	7.1
Performance									
DM intake, kg/d	8.48	8.43	8.51	8.51	8.48	8.46	8.24	8.25	.40
ME intake, Mcal/d[g]	15.8	15.7	17.4	17.4	18.8	18.8	19.9	20.0	—
ADG, kg	.79	.86	.80	.82	.83	.92	.94	.82	.06
Gain/DM intake, g/kg	93.0	101.1	94.1	95.1	96.8	107.6	113.1	97.9	9.2

[a]Indicates – or + ear implant (Synovex-S, 200 mg progesterone plus 20 mg estradiol benzoate).
[b]CP level main effect ($P < .01$).
[c]Calculated as DM intake × analytical CP × 1,000.
[d]Implant main effect ($P < .01$).
[e]CP level × implant interaction ($P < .05$). Within each of the implant treatments, gain/DM intake increased as CP level increased in a quadratic manner ($P < .05$).
[f]Significant contrast for CP level means 8% vs 10, 12, and 14% ($P < .01$).
[g]Calculated as DM intake × estimated ME (NRC, 1984).

a 6% protein diet responded negatively to diethylstilbestrol but when fed a 10% protein diet the response was positive. Preston and Burroughs (1958) did not see a difference in response over protein levels when lambs were treated with diethylstilbestrol; however, protein levels were from 9 to 17%, thus the lower level may not have been limiting. In their study, response tended to be greater with greater energy intakes. Similarly, Klosterman et al. (1958) reported an increased response to diethylstilbestrol in feedlot steers as protein level in the diet increased from 8.3 to 11.1%, whereas Keith et al. (1960) showed no trend in steers as protein level increased from 10 to 12%. Griffiths (1982) did not obtain a difference in response in trenbolone-treated steers when 11.5 and 13.5% dietary protein levels were compared. Keith et al. (1960) and Burroughs et al. (1955) reported a trend toward greater response to diethylstilbestrol in feedlot steers at greater energy intake levels.

The current study clearly demonstrates that protein is the primary factor important for achieving a response to estrogenic growth promoters if energy intake is above maintenance. Both in controlled nitrogen balance trials and in an ad libitum level intake experiment when protein intake was limiting under varying but adequate energy supply, response to Synovex was reduced. Although this study was not designed to study mechanisms, it is consistent with the emerging scenario that protein synthesis is the primary system that is affected by estrogenic growth promoters (Rumsey et al., 1979; Claypoole et al., 1987), and that at least part of this effect on synthesis rate occurs via either an increase in somatotropic binding sites in tissues (Breier, 1988) or an increased release of GH from the pituitary (Preston, 1975), which in turn increases IGF-I (Rumsey and Elsasser, 1989). Increased growth rate resulting from the use of Synovex in beef steers has been shown to be related to increased IGF-I in both plasma and tissues (Rumsey and Elsasser, 1989).

It should also be noted that above an adequate level of dietary protein, as with energy, no further response to an estrogenic growth promoter occurs. This may be related to a large, dynamic urea pool within the ruminant that is recycled back to the rumen for reabsorption. Studies using portal, arterial cannula preparations (G. Huntington and T. Rumsey, unpublished data) indicated that with adequate dietary protein a large amount of urea that typically would be recycled to the rumen was utilized by tissues in Synovex-implanted steers compared with steers not implanted. This did not occur when an inadequate level of dietary protein was fed to these same steers.

Implications

This study was conducted to determine the response to estrogenic growth promoters under varied dietary protein and energy regimens. Feeding low vs moderate DM intake while maintaining protein intake at a constant adequate level did not improve response in terms of daily gain or nitrogen balance. Under feedlot conditions, adequate dietary protein is necessary to achieve maximum response, and increasing dietary energy under conditions of inadequate dietary protein does not improve the response to estrogenic growth promoters. When dietary energy is above maintenance, adequate dietary protein is of primary importance to achieve maximum benefit from estrogenic growth promoters in feedlot cattle.

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